

## DILUTE CLEANING COMPOSITION AND METHOD FOR USING SAME

### Reference to Cross-Related Application

This application is a continuation in part of U.S. Patent application Serial No. 08/808,014 filed 3 March 1997, incorporated herein by reference thereto.

### Field of the Invention

The present invention relates to the fabrication of semiconductor integrated circuits, and in particular, to cleaning compositions and methods for cleaning surfaces during fabrication.

### Background of the Invention

In the fabrication of semiconductor integrated circuits (ICs), active device regions are formed in semiconductor substrates, isolated from adjacent devices with an isolating material. Electrical paths connect such active devices, using thin-film structures, such as metal lines/patterned metal layers. Such structures make contact with active devices through openings, or contact holes, in the isolating material. One primary concern in forming such interconnects is the maintenance of a low level of resistivity throughout an IC in order to ensure devices perform properly. As ICs are scaled down in size, so are the devices which make up the ICs. Increases in resistance are associated with increasing circuit density and adversely affect device performance, slowing them down and increasing power consumption. Thus, ways to decrease the overall resistance of ICs are crucial to continued successful device performance.

In many applications, the metal lines/patterned metal layers are formed on a different level than the active devices, separated by an insulating layer, such as, for example, silicon dioxide or borophosphosilicate glass (BPSG). Furthermore, there may be more than one level of metal lines/patterned metal layers, connected by conductive interconnects formed in vias defined in an insulating layer between adjacent metal lines/patterned metal layers. Commonly used metal lines/patterned metal layers include aluminum, to which copper may be added to form an alloy. Interconnects are also

formed between individual devices and the metal lines/patterned metal layers. A typical interconnect to an active device region is formed in a contact hole defined in an insulating layer over the active device region. The contact hole is filled with one or more metals, such as, for example, aluminum or tungsten.

5 In lowering resistivity of an IC, it is important to remove all foreign residue from interfaces in the IC. As multiple layers are formed in ICs, individual layers may need to be cleaned before the next layer is formed or before surface modification is done. Numerous preclean procedures exist for use prior to semiconductor surface modification in batch furnaces, including wet chemical cleans, hydrogen bakes,  
10 phosphoric acid, and hydrofluoric acid (HF) vapor cleans. Many cleaning compositions undesirably contain strong, i.e., not dilute, organic solvents, which typically are disposed of using special hazardous waste disposal techniques.

Preclean procedures are important to both reduce native oxide and remove other contaminants, such as, for example, residual organic and metallic impurities. Residual  
15 photoresist and other organic materials used in processing steps, such as, for example, etches, are often hard to remove from surfaces during IC fabrication. In particular, such residual materials are hard to remove from metal surfaces and surfaces adjacent to metal layers due to the metallization of such organic residue on the surfaces, particularly as a result of intermixing of materials during etch steps. Thus, metal layers and vias have  
20 been hard to effectively clean in the past after completion of patterning etches and via etches through insulating layers thereon. Further, conventional cleaning compositions used are typically hazardous and require special handling and disposal procedures.

Therefore, for the reasons as described above, there is a need for effective cleaning compositions and methods of cleaning surfaces during fabrication of ICs. For  
25 example, a composition and method for cleaning metal surfaces during fabrication is needed to remove metallized organic residue from surfaces during IC fabrication in order to lower the resistivity of resulting ICs. Further, it is desirable that the cleaning compositions utilized can be disposed of safely and easily.

### Summary of the Invention

A cleaning method in a semiconductor fabrication process according to the present invention includes providing a dilute composition consisting essentially of phosphoric acid and acetic acid and exposing a surface to the dilute composition. In one embodiment of the method, the dilute composition includes phosphoric acid at a concentration of about 5% or less by volume and acetic acid at a concentration of about 30% or less by volume. More preferably, in one embodiment of the dilute composition, the dilute composition includes phosphoric acid at a concentration of about 5% or less by volume and acetic acid at a concentration of about 10% or less by volume. In another embodiment, the dilute composition includes phosphoric acid at a concentration of about 5% or less by volume and acetic acid at a concentration in the range of about 20% by volume to about 30% by volume.

Another cleaning method according to the present invention includes providing a composition comprising phosphoric acid and acetic acid, wherein the composition includes phosphoric acid at a concentration of X%, wherein X is about 5% by volume or less, and acetic acid at a concentration of about (100-X%) by volume or less. A surface is then exposed to the composition. In one embodiment of the method, the composition is a dilute composition, wherein the dilute composition includes phosphoric acid at a concentration of about 5% by volume or less, acetic acid at a concentration of about 30% by volume or less, and deionized water. In another embodiment, the surface is of a conductive layer.

A method of fabricating an interconnect structure according to the present invention is also provided. The method includes patterning a conductive layer and cleaning the conductive layer using a composition comprising phosphoric acid and acetic acid. The composition includes phosphoric acid at a concentration of about X% or less by volume, where X is 5, and acetic acid at a concentration of about (100-X)% or less by volume. In one embodiment of the method, the composition is a dilute composition, and further, the dilute composition includes phosphoric acid at a concentration of about 5% or less by volume and acetic acid at a concentration of about 30% or less by volume. In another embodiment, the dilute composition includes

phosphoric acid at a concentration of about 5% or less by volume and acetic acid at a concentration of about 10% or less by volume.

In another embodiment of the method, the conductive layer comprises aluminum. Further, the patterning may include patterning the aluminum layer using a chlorine-containing etchant and a photoresist which results in organic residue on at least a part of the conductive layer. The cleaning then removes the organic residue, e.g. a metallized organic residue.

In addition, a method of fabricating a multilevel interconnect structure is described. The method includes providing an insulating layer over a first metal layer. A via is defined in the insulating layer resulting in residue on an exposed portion of the first metal layer. The residue is removed using a dilute cleaning composition consisting essentially of phosphoric acid and acetic acid. The dilute cleaning composition includes phosphoric acid at a concentration of about 5% or less by volume and acetic acid at a concentration in the range of about 20% by volume to about 30% by volume.

Yet another method according to the present invention includes providing a structure including an aluminum containing conductive region and providing a dilute composition consisting essentially of phosphoric acid, acetic acid, and deionized water. The structure is then exposed to the dilute composition to clean at least the aluminum containing conductive region. Preferably, the dilute composition includes phosphoric acid at a concentration of about 5% or less by volume and the acetic acid at a concentration of about 30% or less by volume.

In various embodiments of the above methods, the surface is of a conductive layer. Preferably, when exposing the conductive layer to the composition, etching of the conductive layer occurs at a rate of less than about 200 Å/minute. More preferably, such etching of the conductive layer occurs at a rate of less than about 50 Å/minute. Further, preferably, etching of the conductive layer occurs such that less than about 500 Å of conductive material is removed from the conductive layer during an exposure period of less than 10 minutes; preferably, less than about 200 Å during an exposure period of less than 10 minutes; more preferably, less than about 50 Å during an exposure period of less than 10 minutes.

A cleaning composition for use in semiconductor integrated circuit fabrication according to the present invention consists essentially of a dilute aqueous solution of phosphoric acid and acetic acid. The phosphoric acid is of a concentration of about 5% by volume or less and the acetic acid is of a concentration of about 30% by volume or less. Preferably, in one embodiment, the phosphoric acid is of a concentration of about 5% or less by volume and the acetic acid of a concentration of about 10% or less by volume. In another embodiment, the phosphoric acid is of a concentration of about 5% or less by volume and the acetic acid is of a concentration in the range of about 20% by volume to about 30% by volume.

Another cleaning composition for use in semiconductor integrated circuit fabrication according to the present invention includes phosphoric acid and acetic acid. The composition includes phosphoric acid at a concentration of about X% by volume or less, where X is 5, and acetic acid at a concentration of about (100-X)% by volume or less. In one embodiment, the composition is a dilute composition, wherein the dilute composition includes phosphoric acid at a concentration of about 5% by volume or less, acetic acid at a concentration of about 30% by volume or less, and deionized water.

### **Brief Description of the Drawing**

Figures 1A to 1K are cross-sectional representations of a multilevel interconnect structure formed using a cleaning composition including phosphoric acid and acetic acid in accordance with the present invention, and intermediate structures thereof.

### **Description of the Embodiments**

In the following detailed description, reference is made to the accompanying Figures which form a part hereof, and in which is shown by way of illustration specific embodiments in which the invention may be practiced. These embodiments are described in sufficient detail to enable those skilled in the art to practice the invention, and it is to be understood that other embodiments may be utilized and that changes may be made without departing from the scope of the present invention as defined in the accompanying claims. For example, the terms wafer and substrate used herein include any semiconductor-based structure. Both are to be understood as including silicon-on-

sapphire (SOS) technology, silicon-on-insulator (SOI) technology, doped and undoped semiconductors, epitaxial layers of silicon supported by a base semiconductor, as well as other semiconductor-based structures well known to one skilled in the art.

Furthermore, when reference is made to a wafer or substrate in the following

5 description, previous process steps may have been utilized to form regions/junctions in the semiconductor-based structure previously formed. The following detailed description is, therefore, not to be taken in a limiting sense, and the scope of the present invention is defined by the appended claims.

10 Generally, a chemical composition in accordance with the present invention for use in wet cleans in semiconductor processing includes both phosphoric acid and acetic acid. The chemical composition preferably includes about 5 % by volume or less of phosphoric acid with the remaining portion of the composition being acetic acid or with the remaining portion being acetic acid and deionized water. In other words, the composition includes about X% by volume or less of phosphoric acid and about (100-  
15 X)% by volume or less of acetic acid, where X is 5. This chemical composition provides better solvation of metallized polymers and organic polymers than previously used cleaning compositions, such as standard phosphoric acid cleans. However, the chemical composition prevents removal of too much material from the surface being cleaned, e.g., an aluminum containing surface. The use of both acidic components  
20 together in the cleaning composition is beneficial. The phosphoric acid component promotes solvation of inorganic residue, while the acetic acid component promotes solvation of organic residue. Further, and surprisingly, acetic acid passivates a metal containing surface being cleaned, e.g., patterned aluminum, so as to prevent undesirable removal of substantial amounts of the metal by the phosphoric acid during the cleaning  
25 process.

Preferably, the chemical composition is a dilute composition. Dilute refers to a composition having about 35% reactive components or less by volume. The dilute chemical composition is advantageous as compared with previously used strong (i.e., not dilute) solution cleans because it does not require special hazardous waste disposal.  
30 Acetic acid is a mild organic reactant and the concentration at which it is preferably used in the preferred dilute compositions according to the present invention is safe and

would generally not require the use of special exhaust hoods (e.g., VOC hoods) when used to perform a cleaning operation. Preferably, the concentration of phosphoric acid in the dilute chemical composition is about 5% by volume or less. The concentration of acetic acid in the dilute solution is about 30% by volume or less. The wet etch using the dilute composition is generally performed over a certain time period, e.g., the time period during which the structure being cleaned is immersed in the dilute solution. Preferably, this time period is in the range of about 15 seconds to about 10 minutes. More preferably, the time period is in the range of about 15 seconds to 5 minutes, and yet more preferably in the range of about 15 seconds to 90 seconds.

Different preferred chemical concentrations for the dilute composition including phosphoric acid and acetic acid may be used depending upon the structure to be cleaned. With respect to patterned metal surfaces, e.g., patterned aluminum layers, to be cleaned, preferably, the concentration of phosphoric acid in the dilute chemical composition is about 5% by volume or less. The concentration of acetic acid in the dilute solution is preferably about 30% by volume or less; more preferably about 10% by volume or less. The reactive components are diluted in any suitable solvent, preferably, deionized water. If the concentration of the phosphoric acid component is increased above 5%, excess metal loss may undesirably result from the surface being cleaned. The concentration of the two acidic components is such that effective removal of residue on a surface, particularly metallized organic residue, is accomplished. As used herein, patterned metal surfaces refers to surfaces of structures that do not include an opening defined therein which exposes an underlying metal layer, e.g., oxide layers patterned with vias to expose an underlying metal layer. Preferably, the structure including the patterned metal surfaces is immersed in the dilute composition for about 15 seconds to about 90 seconds, although the structure may be immersed in the dilute composition for longer times.

With respect to etched openings and/or metal surfaces at the bottom of such openings (e.g., aluminum at the bottom of a via of an interconnect system, metal in a contact opening, etc.), preferably, the concentration of phosphoric acid in the dilute chemical composition is about 5% by volume or less. The concentration of acetic acid in the dilute solution is in the range of about 20% by volume to about 30% by volume.

The reactive components are diluted in any suitable solvent, preferably in deionized water. Again, if the concentration of the phosphoric acid component is increased above 5%, excess metal loss may undesirably result from the surface being cleaned.

Preferably, the structure including the etched openings is immersed in the dilute composition for a time period of about 15 seconds to about 90 seconds. More preferably, the structure is immersed in the dilute composition for about 30 seconds.

Although different concentrations of acidic components may be used in the dilute compositions for different cleaning applications, preferably the dilute composition is such that when used to clean surfaces having exposed metals, e.g., aluminum, less than 500 Å of the metal is removed during the cleaning process. More preferably, less than 200 Å of the exposed metal is removed, and further, yet more preferably, less than 50 Å of the exposed metal is removed. The wet etch rate for the metal during the clean is preferably less than about 200 Å/minute, more preferably less than about 50 Å/minute.

Preferably, the chemical composition is heated above ambient temperature in a circulating bath prior to its use. The chemical composition is heated to about 50 degrees Celsius or less. If higher temperatures are used, the integrity of underlying metallic layers is possibly degraded. Preferably, temperatures of about 30 to about 45 degrees Celsius are used for optimizing the cleaning abilities without severe metal loss from underlying layers when the concentration of the phosphoric acid component present in the composition is of an amount of about 5% or less by volume. When lower concentrations of the phosphoric acid component are present in the composition, higher temperatures may be effectively used without severe metal loss from underlying layers. Similarly, when higher concentrations of the phosphoric acid component are present in the composition, lower temperatures may need to be used to avoid severe metal loss from underlying layers.

The chemical composition of the present invention is typically used for cleans performed in the fabrication of an interconnect structure. For example, the present invention is useful for cleans performed in fabricating a multilevel interconnect structure. Interconnect structure, as used herein, refers to vias, contacts, metal lines/patterned layers, pads, and similar conductive circuitry utilized in an integrated



circuit. Figures 1A to 1K illustrate a multilevel interconnect structure and intermediate structures thereof. Dimensions and scaling in the Figures are not exact, but represent the nature of fabricating a multilevel interconnect structure in general and the necessity for utilizing the chemical composition of the present invention for cleaning intermediate structures thereof.

In the fabrication of a multilevel interconnect structure, a contact hole 18 is typically defined in an insulating layer 20, such as, for example, borophosphosilicate glass (BPSG), as illustrated in Figure 1A. The contact hole 18 is defined over an active area of an underlying substrate, as represented generally by 22. An interconnect structure 24 is then formed in the contact hole 18 using any suitable materials and methods for forming the same. Typical interconnect 24 fabrication includes formation of a series of layers, such as, for example, titanium silicide, titanium nitride, and a metal plug or other conductive layers. Next, a blanket layer of metal 26 is deposited over the interconnect structure 24 and insulating layer 20, to produce the structure illustrated in Figure 1A. The metal layer 26 can be any conductive material, such as, for example, aluminum or aluminum alloyed with copper. Other elements that can constitute the conductive material include titanium and silicon.

A photoresist layer 28 is then deposited on the metal layer 26 and patterned as well known to one skilled in the art, resulting in the structure illustrated in Figure 1B. The metal layer 26 is then etched in exposed areas, resulting in the metal line structure illustrated in Figure 1C.

The etchant used to pattern the metal layer 26 varies. For patterning aluminum, chlorine-containing etchants are typically used, i.e., for example,  $\text{Cl}_2$ ,  $\text{BCl}_3$ ,  $\text{CCl}_4$ ,  $\text{SiCl}_4$ , and combinations thereof. However, the exact nature of the etchant is not critical to the scope of the invention.

Residue 29, such as organic residue of etch-related polymers, often remains on the exposed metal 26 surface. Depending on the constituent elements of the exposed metal surface 26, the etchant, and the etch-related polymers, the chemical nature of the residue 29 varies. For example, titanium, aluminum, copper, and silicon are common elements utilized in semiconductor fabrication. Carbon, chlorine, and fluorine are common elements utilized in etchants. Carbon and nitrogen are common elements

present in etch-related polymers. These elements, or combinations thereof, are typically found in residue 29 on such surfaces 26. Furthermore, oxygen may be present in the residue 29 as a result of the etch-related polymer stripping, for example, when using an oxygen ash for removal of photoresist. In particular, when the etchant contains  
5 chlorine, the organic residue often includes aluminum chloride or copper chloride, for example, when the exposed metal 26 surface is aluminum or aluminum alloyed with copper.

In order to prepare the surface of the structure illustrated in Figure 1C for insulating layer deposition, the photoresist layer 28 is next removed. To remove the  
10 photoresist layer 28 and/or other etch-related polymers after patterning the first metal layer 26, an oxygen ash is commonly used, or any suitable method (wet or dry), as well known to one skilled in the art. For example, a typical oxygen ash includes heating the structure in a process chamber having a temperature of about 200 to 300 degrees Celsius and in the presence of an oxygen-containing plasma. Other examples include heating  
15 the structure in the presence of an ozone-containing environment or wet cleaning the structure using organic strippers.

Even after the oxygen ash step, residue 29, such as organic components from the photoresist 28 often remain on the first metal layer 26, as illustrated in Figure 1D. If not removed, such residue 29 increases the resistivity of the interconnect structure,  
20 degrading electrical performance. The longer the first metal layer 26 is exposed to the photoresist 28 during the etch process, the harder it becomes to effectively remove all of the residue 29, such as organic residue, from the surface of the first metal layer 26. This is due to the fact that the organic materials become metallized, as previously mentioned. Thus, the structure illustrated in Figure 1D is exposed to the cleaning composition of  
25 this invention after the oxygen ash step. The exposure time needed for effectively cleaning the metallized organic residue 29 varies. The exposure time is adjusted to allow for adequate cleaning without removing excess metal from underlying surfaces. As one example, an exposure time of about 90 seconds seems to provide an adequate balance between these two competing factors, such as, for example, when using  
30 concentrations of about 10% by volume of acetic acid in addition to about 5% by volume of phosphoric acid and temperatures of about 30 to about 45 degrees Celsius.

The cleaning composition of this invention is more effective than conventionally used standard phosphoric acid compositions at removing such residue 29, including any metallized organic elements, due to the acetic acid component passivating the metal surfaces preventing over etching of the metal during the clean.

5 After the first metal layer 26 is patterned and cleaned with the chemical composition of this invention, an insulating layer 30 is formed over the first metal layer 26, as illustrated in Figure 1E. The insulating layer 30 can be any dielectric material, such as, for example, silicon dioxide, spin-on-glass, or borophosphosilicate glass. Typically, the insulating layer 30 has a low dielectric constant and is formed at  
10 relatively low temperatures. Silicon dioxide may be used for the insulating layer 30. The silicon dioxide 30 is formed using any well known technique, such as, for example, tetraethyloxysilicate (TEOS)-based plasma-enhanced chemical vapor deposition (PECVD). The thickness of the insulating layer 30 is determined according to the feature sizes of the integrated circuit as well known to one skilled in the art.

15 To define a via in the insulating layer 30, a photoresist layer 28 is patterned over the insulating layer 30, as illustrated in Figure 1E. The via 32 is then defined in the exposed portions of the insulating layer 30 by etching away the exposed insulating layer 30, the resulting structure of which is illustrated in Figure 1F. The etchant used to define the via 32 varies. Typical etches often comprise more than one step. For  
20 example, to define a via 32, a wet etch at standard temperature may be followed by a dry etch (i.e., plasma etch), two adjacent dry etches may be used instead, or a single dry etch may also be used.

For etching silicon dioxide, plasma etchants often contain a fluorine component. Typical etchants include, but are not limited to,  $\text{CF}_4$ ,  $\text{C}_2\text{F}_6$ ,  $\text{C}_3\text{F}_8$ ,  $\text{CHF}_3$ ,  $\text{NF}_3$ ,  $\text{SF}_6$  and  
25 combinations thereof. Once again, residue 29, such as organic residue of etch-related polymers, often remains on the exposed metal 26 surface. As previously described, however, the chemical nature of such residue 29 varies depending on the constituent elements of the exposed metal surface 26, the etchant, and the etch-related polymers. In particular, when the etchant contains fluorine, the residue 29 often includes metal  
30 fluorides, such as, for example, aluminum fluoride, if the exposed metal 26 is aluminum.

In order to prepare the surface for the next metal layer deposition, the photoresist layer 28 is removed, resulting in the structure illustrated in Figure 1G. To remove the photoresist layer 28 and/or etch-related polymers after defining the via 32, an oxygen ash, or any suitable method, is commonly used, as described previously.

5        After the oxygen ash step, residue 29, such as organic components from the photoresist 28 often remain on the first metal layer 26 at the bottom of the via and on the sidewalls of the via 32 at the insulating layer 30 interface. The longer the first metal layer 26 is exposed at the bottom of the via 32, the harder it becomes to effectively remove all of the residue 29 at the bottom of the via 32. This is due to the fact that the  
10       organic materials become metallized, as previously described. Thus, the structure illustrated in Figure 1G is exposed to the cleaning composition of this invention after the oxygen ash step.

      The exposure time needed for effectively cleaning the metallized organic residue 29 varies. The exposure time must be adjusted to allow for adequate cleaning without  
15       removing excess metal from underlying surfaces. As one example, an exposure time of about 30 seconds using a dilute solution of about 25% by volume of acetic acid and 5% by volume of phosphoric acid seems to provide an adequate balance between these two competing factors.

      The cleaning composition of this invention is more effective than conventionally  
20       used phosphoric acid compositions at removing such residue 29. However, while piranha cleans (i.e. mixtures of hydrogen peroxide and sulfuric acid) are used for cleaning contact holes, they cannot be used for cleaning vias 32 and metallic surfaces 26, due to their extreme reactivity. The extreme reactivity of such conventional cleans results in severe metal loss from exposed metal surfaces.

25       Next, as illustrated in Figure 1H, an interconnect structure 34 is formed in the via 32 and a second metal layer 36 is formed over the insulating layer 30 and structure 34. The second metal layer 36, like the first metal layer 26 and any subsequent metal layers, can be any conductive material, such as, for example, aluminum or aluminum alloyed with copper. Furthermore, the conductive material constituents can include  
30       titanium and/or silicon. The second metal layer 36 is then patterned, as well known to one skilled in the art. A patterned photoresist layer 28 is formed over the second metal

layer 36, as illustrated in Figure 1H. The second metal layer 36 is then etched in exposed areas, the resulting structure of which is illustrated in Figure 1I. The resulting structure often undesirably contains residue 29, such as organic residue, on the exposed surfaces of the second metal layer 36. The etchant used to pattern the second metal layer 36 varies, as described previously, contributing to the presence of the residue 29 on the metal surfaces.

In order to prepare the surface of the structure illustrated in Figure 1I for deposition of subsequent layers, the photoresist layer 28 is next removed. To remove the photoresist layer 28 and/or etch-related polymers after patterning the second metal layer 36, an oxygen ash, or any suitable method, is commonly used, as described previously.

After the oxygen ash step, residue 29, such as organic components from the photoresist 28, often remain on the second metal layer 36, as illustrated in Figure 1J. The longer the second metal layer 36 is exposed to the photoresist 28 during the etch process, the harder it becomes to effectively remove all of the residue 29 from the surface of the second metal layer 36. This is due to the fact that the organic materials become metallized, as described previously. Thus, the structure illustrated in Figure 1J is exposed to the cleaning composition of this invention after the oxygen ash step. The exposure time needed for effectively cleaning the metallized organic residue 29 varies. The exposure time must be adjusted to allow for adequate cleaning without removing excess metal from underlying surfaces. As one example, an exposure time of about 90 seconds seems to provide an adequate balance between these two competing factors, when using concentrations of about 5% by volume of phosphoric acid along with about 10% by volume of acetic acid and temperatures of about 30 to about 45 degrees Celsius.

If the multilevel interconnect structure includes more than two levels of metal, subsequent insulating layers, vias, and metal layers are formed thereon, as described previously and represented generally as 38 in Figure 1K. The intermediate structures are cleaned in the phosphoric acid/acetic acid composition of the present invention, as described previously. However, not every surface clean must be performed with the cleaning composition of the present invention, but it is advantageous to do so for

achieving optimum electrical performance. The present cleaning composition may be used for one or more of the cleans when forming a multilevel interconnect structure.

The chemical composition of the present invention effectively removes metallized organic residue from metal surfaces, without deleteriously removing too much of the metal surface. By removing such residue, resulting resistivity of an IC is lowered. This is critical for the continued increase in device density, enabling fabrication of faster ICs with lower power consumption. Furthermore, due to the absence of strong organic solvents in the dilute chemical composition, use of the cleaner is even more desirable because it doesn't require special hazardous waste disposal procedures.

#### Example

Twenty-five wafers, each having two different sized vias and patterned aluminum lines were prepared by forming patterned lower level aluminum lines on a substrate assembly surface, forming TEOS on the aluminum lines, patterning the TEOS using a photoresist to define the vias, etching the vias to the lower level aluminum lines using a fluorine plasma dry etch (including  $\text{CF}_4$  and  $\text{CHF}_3$ ), removing photoresist using an oxygen ash, and cleaning the vias using the cleaning compositions given below in Table 1. Thereafter, the vias are filled with aluminum and upper level aluminum lines are formed by defining the upper level aluminum lines in a layer of aluminum using photoresist, etching the upper level aluminum lines using a chlorine plasma dry etch (including  $\text{Cl}_2$  and  $\text{BCl}_3$ ), removing the photoresist using an oxygen ash, and then cleaning the upper level aluminum lines using the cleaning compositions given below in Table 1. The vias of the first type had dimensions of about 0.6 microns with the vias of the second type having dimensions of about 0.48 microns. The upper level aluminum lines are of a thickness of about 6000 Å.

The wafers were grouped into lots of five. Each lot of five wafers were immersed in a dilute composition having the concentrations given below in Table 1 for a process time also given in Table 1. The acetic acid concentrations are in volume percent. The acetic acid was added to an existing mixture of 5% phosphoric acid in deionized water. The resistance values of the vias and patterned metal lines were measured after the clean was performed. Each wafer had fifty probe points used for

each resistance determined, i.e., fifty probe points for the via of the first type, fifty for the via of the second type, etc. In all cases the resistance values are optimum when they are at the lowest mean values and have the lowest standard deviation. As shown below in Table 1, the best dilute composition for via cleaning resulting from this Example would be the composition including the 25% acetic acid concentration with the wafer immersed for about 30 seconds. The best dilute composition for cleaning surfaces having exposed patterned metal would be the composition having the 10% acetic acid concentration with the wafer immersed for about 90 seconds.

Table 1

| Acetic Acid<br>% by vol. | Process<br>Time | First Via Type                   | Second Via Type                    | Patterned Metal<br>Line             |
|--------------------------|-----------------|----------------------------------|------------------------------------|-------------------------------------|
| 5%                       | 90 seconds      | mean: 42.522<br>std. dev.: 6.978 | mean: 117.195<br>std. dev.: 26.797 | mean: 1090.135<br>std. dev.: 13.803 |
| 10%                      | 90 seconds      | mean: 41.171<br>std. dev.: 6.408 | mean: 112.608<br>std. dev.: 26.124 | mean: 1060.995<br>std. dev.: 4.422  |
| 25%                      | 90 seconds      | mean: 36.076<br>std. dev.: 6.001 | mean: 89.017<br>std. dev.: 20.695  | mean: 1089.61<br>std. dev.: 19.631  |
| 25%                      | 30 seconds      | mean: 27.564<br>std. dev.: 1.405 | mean: 60.734<br>std. dev.: 16.436  | mean: 1112.307<br>std. dev.: 32.365 |
| 0%                       | 90 seconds      | mean: 31.151<br>std. dev.: 5.692 | mean: 69.929<br>std. dev.: 35.76   | mean: 1113.156<br>std. dev.: 19.699 |

It is to be understood that the above description is intended to be illustrative, and not restrictive. Many other embodiments will be apparent to those of skill in the art upon reviewing the above description. For example, the chemical cleaning composition of this invention is particularly useful wherever a metal surface needs to be cleaned during the fabrication process. The scope of the invention should, therefore, be determined with reference to the appended claims, along with the full scope of equivalents to which such claims are entitled.